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Sealing Technologies Trade-off for a Phobos Sample Return Mission

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Abstract

The Phobos Sample Return Mission (PhSR) is a phase of the Mars Robotic Exploration Preparation program, with the main objective to acquire and return 100 grams of Phobos soil (regolith) on Earth. First, a complete surface map with topographic and mineralogical information will be obtained by the spacecraft. After a successful sampling, an ERV containing the ERC with the regolith sample will head back to the Earth. Following touch-down, the ERC will be retrieved and opened in a dedicated environment. Given the importance and value of such return sample, it must be well protected between the moments when the ERC is closed on Phobos after the sampling operation until landing on Earth surface. Thus, a special containment system is necessary, capable of withstanding the harsh space environment and the mechanical stress occurred during the mission, while preserving the integrity of the regolith sample. Following previous sampling missions (Hayabusa, Stardust) and the problems raised by the contamination, one can say that the sealing system is probably the most important part of a sample containment system, as it shall protect the sample from Earth contaminants, but also to protect the Earth against possible micro-organisms or other hazardous substances found in space. This paper aims to analyse a variety of sealing technologies with importance in space applications like a sample return mission, measuring qualitatively and quantitatively the performance of a sealing technology when it comes to fulfilling a series of requirements imposed by the sample return mission profile. Using these requirements and mission data as inputs, a trade-off analysis was made, to identify the most suitable sealing technology for a PhSR Mission. It was concluded that sealing technologies such as O-rings and Gaskets can be successfully used in these kind of missions, paying also attention to a proper design of the containment system.

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1. Introduction

Sample return missions represent one of the best opportunities to find more details (origin, composition, existence of micro-organisms, etc.) about the objects in our Solar System, details which cannot be determined at the landing site due to constraints like the available power, the mass of the equipment, the precision of the operations etc., attributed to the spacecraft. Also, as the technology progresses in time, the acquired samples can be restudied, making them a valuable scientific resource available for the future. [1]

Orbiting around Mars, Phobos is a low-gravity object, with great physical and scientific importance, as its origins are still a mystery. Along with its "brother", Deimos, Phobos' composition may provide information about objects from outer solar system, as well as information about the Martian surface material following impact ejecta. All this information can answer lots of questions concerning a future human exploration of the Mars system. [2]

In the frame of the Mars Robotic Exploration Preparation (MREP) program, ESA is considering a Mars Sample Return (MSR) mission as a long-term objective, progressing step-by-step towards this objective through short and medium-term MSR-related technology developments, which are validated during intermediate missions. In this sense, ESA is currently assessing a Phobos Sample Return mission (PhSR) as a phase of the MREP program. The goal of this mission is to collect and return Phobos surface material (regolith) in access of 100 g to Earth.

Concluding, a Phobos Sample Return mission is a great opportunity to answer the questions mentioned above: the Mars moons origins, the early geological history and composition of Mars, all these leading to the preparation of a future human exploration with European contribution to the Mars Sample Return. This opportunity also targets the validation of several critical technologies for the MSR like: sampling, sample transfer and sealing, Earth Return Capsule and Sample Receiving Facility.

Nomenclature

COMOTI	National Research and Development Institute for Gas Turbines
COSPAR	Committee on Space Research
ERC	Earth Re-entry Capsule
ERV	Earth Return Vehicle
ESA	European Space Agency
FEA	Finite Element Analysis
MREP-2	Mars Robotic Exploration and Preparation
MSR	Mars Sample Return
PhSR	Phobos Sample Return
S/C	Spacecraft
SC	Sample Container
TRL	Technology Readiness Level

2. Sample Return missions – advantages and difficulties

The analysis of the soil composition of other planets contributes to the understanding of our Solar System, a sample return mission bringing many advantages in this regard. One of them is the development of advanced state-of-the-art technologies which are used to analyse the extra-terrestrial samples, as the analysis requires precision, sensitivity, resolution and reliability. As the analyses technologies advance, the acquired samples can be re-examined to come up with new data about the sample's originating object. Furthermore, the laboratory analysis is not limited by the constraints imposed on the spacecraft by the mission profile in terms of electrical power, mass of the equipment to be

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